Technical Note

Technique for Intraoperative Neuromonitoring During Periacetabular Osteotomy After Concomitant Hip Arthroscopy

Anthony Soto, B.S., Layla A. Haidar, B.S.A., Scott Crosby, C.N.I.M., Erin Orozco, B.S., and Alfred Mansour III, M.D.

Abstract: Intraoperative neurologic injury during periacetabular osteotomy (PAO) for the treatment of symptomatic acetabular dysplasia is a major complication that can lead to permanent disability and limit the benefit of correcting the acetabular dysplasia. Current literature reflects the evolution of hip-preservation surgery for symptomatic acetabular dysplasia to include hip arthroscopy to address the intra-articular abnormalities, including labral tears, chondral lesions, and femoral cam morphology. A growing number of young hip surgeons and surgeon teams are subscribing to this approach and now performing concomitant hip arthroscopy and PAO. The value of intraoperative neuromonitoring cannot be understated, both in terms of surgeon confidence as well as patient safety, particularly during the learning curve of PAO, with or without hip arthroscopy. We present our current technique for the application of neuromonitoring to allow free mobility of the operative leg and continuous monitoring during PAO. This reproducible technique allows the use of nonsterile neuromonitoring to be used through a sterile conduit, positioned to allow free mobility of the operative extremity and performance of the PAO. We believe this technique provides additional safety benefit and increases awareness regarding neurologic compromise, particularly for the low-volume PAO surgeon or during the procedural learning curve.

Intraoperative neurologic injury during periacetabular osteotomy (PAO) for the treatment of symptomatic acetabular dysplasia is a major complication that can lead to permanent disability and limit the benefit of correcting the acetabular dysplasia. Early descriptions of the PAO technique briefly describe the use of intraoperative neuromonitoring (IONM) but more currently published trends by high-volume experienced PAO surgeons indicate that most no longer use this technique.

From the Department of Orthopaedic Surgery, McGovern Medical School, University of Texas Health Science Center at Houston, Houston, Texas, U.S.A.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

This study was performed at the University of Texas Health Science Center at Houston, Houston, TX.

Received May 4, 2020; accepted August 6, 2020.

Address correspondence to Alfred Mansour, III, M.D., 6400 Fannin, Suite 1700, Houston TX 77030. E-mail: Alfred.A.Mansour@uth.tmc.edu

2212-6287/20760

https://doi.org/10.1016/j.eats.2020.08.005

Current literature also reflects the evolution of hip-preservation surgery for symptomatic acetabular dysplasia to include hip arthroscopy to address the intra-articular abnormalities, including labral tears, chondral lesions, and femoral cam morphology. A growing number of young hip surgeons and surgeon teams are subscribing to this approach and now performing concomitant hip arthroscopy and PAO.

The value of IONM cannot be understated, both in terms of surgeon confidence as well as patient safety, particularly during the learning curve of PAO, with or without hip arthroscopy. We present our current technique for the application of neuromonitoring to allow free mobility of the operative leg and continuous monitoring during PAO.

Indications

The general indications for PAO include symptomatic acetabular dysplasia such as persistent pain for greater than 6 months in the inguinal and/or trochanteric areas, clinical examination including adequate range of motion of the hip and joint congruity, evidence of residual hip dysplasia in radiographs, absent-to-mild osteoarthritis of the hip (Tönnis 0 or 1), and age 13 to 45 years (in patients with developmental dysplasia of the hip), as well as

Table 1. Advantages and Disadvantages of IONM During PAO With or Without Concomitant Hip Arthroscopy

Advantages	Disadvantages
• Allows continuous peripheral neurologic monitoring and real-time feedback throughout osteotomy procedure • Allows free positioning of the operative extremity to maintain mobility during the PAO portion	• Potential source of surgical-site contamination if covered leads become exposed • Added anesthetic/surgical transition time from arthroscopic to open portion for lead placement and obtaining baseline motor and sensory waveforms • Operator-dependent quality of lead placement and interpretation may limit value of neuromonitoring or provide inconsistent feedback

IOMN, intraoperative neuromonitoring; PAO, periacetabular osteotomy.

maintained cartilage integrity using delayed gadolinium-enhanced magnetic resonance of cartilage.[1-3]

Neuromonitoring may not be practical in all major hip surgeries; however, it may be helpful in assuring patient safety in high-risk cases, including those with prolonged surgical time and PAO (see Table 1 for Advantages and Disadvantages). A small study by Sutter et al.,[4] revealed alerts to possible sciatic and/or femoral nerve lesions were more frequently given during PAO compared with other major hip surgeries. In a limited study by Sierra et al.,[5] the sciatic nerve was found to be the most at risk.

Considerations for Anesthesia

Studies have demonstrated a preference for the use of total intravenous anesthesia, such as propofol or remifentanil, for patients using IONM. Moreover, neuromuscular-blocking agents should be avoided if the neuromonitoring involves the use of electromyography; however, propofol and the short-acting neuromuscular-blocking agents, such as succinylcholine, may be used for intubation. Before beginning IONM and surgery, 4/4 muscle twitches should be produced using neuromuscular or train-of-four monitoring. During the operation, anesthesia should notify the IONM team when administering medication that may interfere with the modalities being used.[6]

Monitoring Methodology

IONM was performed throughout each procedure by a certified IONM technologist (Certification for Neurophysiological Intraoperative Monitoring, CNIM) with remote online supervision provided by a board-certified neurophysiologist. Propofol and short-to medium-acting neuromuscular blocking agents were administered to facilitate intubation. Baseline anesthetic levels and vital signs were taken to correlate to IONM baseline data, and anesthetic levels and vital signs were recorded at regular intervals throughout the procedure. A bite block consisting of rolled 4 × 4 gauze was placed between the patient's molars to protect from incidental tongue injury due to contraction caused by stimulation of the temporalis muscle during triggering of transcranially elicited myogenic motor-evoked potentials (mMEPs). For all evoked potentials, baselines were acquired following patient positioning and before incision. Trials were repeated at each critical stage of the procedure, and final recordings were taken at closure. The surgical team was informed of any changes to IONM data and spontaneous electromyographic firing immediately as they were observed. Alarm criteria used were an amplitude decrement of greater than 50% compared with baseline and a latency increase of greater than 10% compared with baselines for somatosensory-evoked potentials (SSEPs) as recommended by the American Clinical Neurophysiology Society. The alarm criteria for reporting mMEP changes were based on the prevailing all-or-none criteria in which a complete abolishment of the signal was deemed to be clinically significant, whereas a partial reduction in amplitude or minor change in morphology was deemed to be likely caused by fluctuating

Fig 1. The positioning of needle sites (blue arrows) and wires. Distal wire ends are coiled and attached to foot (orange arrow) while the lower extremity is being prepped.

Fig 2. Leg is placed in a stockinette and overwrapped in self-adherent wrap (orange arrow). Radiofrequency wand cover used to encase neuromonitoring wires (blue arrow), retrieved by CNIM technician.

anesthetic concentrations or systemic physiological changes. All neurophysiologic changes were compared with correlating anesthetic levels and vital sign physiologic measurements at the time of observed change and referenced to documented baseline levels to evaluate for clinical significance. Technical troubleshooting was carried upon observing any change meeting alarm criteria to rule out potential technical cause.

SSEPs were recorded following stimulation via sterile subdermal needle electrodes placed over both the tibial nerve and the common peroneal nerve in the operative leg and in the nonoperative leg as a control for systemic physiological changes or anesthetic related changes. Stimulation was delivered via constant current monophasic square wave pulses of 0.2-ms duration at a rate of 3.79 pulses/s. Recording was performed via sterile subdermal needle electrodes placed over the somatosensory cortices according the international 10/20

Fig 3. Sterile conduit (blue arrow) is being created using self-adherent wrap over the wand cover.

Fig 4. Completed sterile conduit (black arrow) to allow free mobility after sterile U drape placement (orange arrow), and incision drape placed.

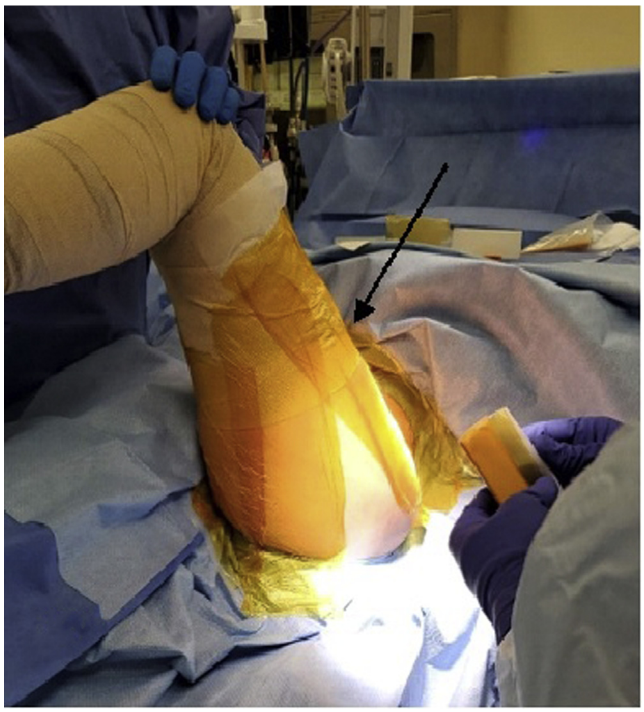

Fig 5. Iodine-impregnated incision drape (black arrow) is being applied in strips to the thigh, covering remaining exposed skin and the surgical site.

Table 2. Pearls and Pitfalls for IONM During PAO With or Without Concomitant Hip Arthroscopy

Pearls	Pitfalls
• Obtain fluoroscopic image after lead and wire placement before draping to confirm wires do not obscure pelvic imaging • Have all wires including perineal region exiting distally to prevent interfering with fluoroscopic imaging • Apply the self-adherent wrap loosely on the leg to prevent overcompression of the wires against the skin or compromise vascular flow • Completely cover the leads with the impervious stockinette • Obtain motor-evoked potentials before and after each at-risk portion of the case	• Coiling the wires in the path of the fluoroscopic imaging and interfering with image quality • Not adequately securing leads with adhesive dressing and inadvertently disengaging them during draping • Not creating a long-enough sterile conduit and limiting motion of the extremity • Not coordinating with anesthesia to correctly delivery TIVA for accurate neuromonitoring

IOMN, intraoperative neuromonitoring; PAO, periacetabular osteotomy; TIVA, total intravenous anesthesia.

system of electrode placement at C3′ and C4′, referenced to a common reference placed at Fpz, as well as far-field subcortical recordings recorded from an electrode placed at Cs5 and referenced to Fpz. SSEP recordings were averaged with 300 trials per average to increase the signal to noise ratio and resolve the signals for ease of interpretation.

Transcranially elicited mMEPs were performed by stimulating via sterile subdermal needle electrodes placed at electrode sites C3 and C4 of the international 10-20 system and recording from contralateral biceps femoris, tibialis anterior, gastrocnemius referenced to peroneus longus, and first dorsal interossei of the foot referenced to abductor hallucis muscles via pairs of sterile subdermal needle electrodes placed over each muscle group. Stimulus parameters for elicitation of mMEPs were constant voltage pulses of 7 per train delivered with an interstimulus interval of 2.5 ms and 50-microsecond pulse width. Stimulus intensity ranged from 200 V to a maximum of 800 V. Recordings from the thenar referenced to the hypothenar eminences of the hands were performed to control for anesthetic related changes. Trials were performed via anodal stimulation with normal polarity for left sided recordings and with reversed polarity for right sided recordings.

Spontaneous electromyography was recorded continuously during the procedure via the same pairs of sterile subdermal needle electrodes placed for mMEP recording with additional pairs placed in the bulbospongiosus and external anal sphincter for monitoring of the lower sacral nerve roots. Spontaneous neurotonic discharges were reported to the surgeon as they were observed during surgical manipulation.

Surgical Technique

Patient Preparation and IONM Placement

The patient is transferred to a flat-top radiolucent table after the concomitant hip arthroscopy portion and before the PAO. The neuromonitoring leads are then placed on the head, upper extremities, perineal region, and operative and nonoperative legs. Multiple transparent occlusive adhesive dressings (Tegarderm; 3M Health Care, St. Paul, MN) are then placed over the needle insertion sites and along the length of the wires to the foot to allow the leg and adhesive dressings to be prepped using a standard surgical prep. The distal ends of the wires are then coiled at the foot and provisionally held within a surgical glove taped to the foot to maintain position (Fig 1).

The operative leg is prepped and then an impervious stockinette with a slit cut into the end is placed over the leg and brought to the mid-thigh, covering all of the leg electrodes. The stockinette is overwrapped with self-adherent wrap while flexing the knee to 90°, wrapping from the ankle to the proximal thigh covering the proximal end of the stockinette. A sterile RF wand cover (RF Surgical Systems, Carlsbad, CA) with a slit cut at the end is then placed over the distal end of the stockinette and held at the ankle. The CNIM technician then retrieves the distal end of the wires through the slits and pulls the wand cover over the wires to create a "sterile tail." Another roll of 6-inch self-adherent wrap is used to overwrap the ankle and wand cover containing the wires to create a sterile conduit of sufficient length to allow free mobility of the operative leg without compromising neuromonitoring or sterility (Figs 2 and 3). A sterile U-drape is then placed at the lower end of the bed to maintain the position of the sterile tail and occlude the transition zone where the unsterile wires exit and are connected to the neuromonitoring unit (Fig 4). Lastly, an iodine-impregnated incision drape (Ioban 2 Antimicrobial Incise Drape; 3M Health Care) is used to cover the remaining skin of the thigh and hip of the operative leg (Fig 5) (see Table 2 for pearls and pitfalls of the application).

PAO is then performed as previously detailed in previous articles.[7]

IONM is performed in a continuous fashion until the PAO fragment has been stabilized and no further manipulation is anticipated. Standard mMEPs are obtained after each major osseous cut to confirm baseline and then requested as needed throughout the procedure, particularly during the posterior column cut to ensure no wayward osteotome placement has compromised the sciatic nerve.

Conclusions

We present our current technique for IONM during PAO, with or without concomitant hip arthroscopy. This reproducible technique allows the use of nonsterile neuromonitoring to be used through a sterile conduit, positioned to allow free mobility of the operative extremity and performance of the PAO. We believe this technique provides additional safety benefit and increases awareness regarding neurological compromise, particularly for the low-volume PAO surgeon or during the procedural learning curve.

Acknowledgments

The authors acknowledge Dr. Travis Heare for his mentorship and detailed teaching of the neuromonitoring process during PAO.

References

1. Ganz R, Horowitz K, Leunig M. Algorithm for femoral and periacetabular osteotomies in complex hip deformities. *Clin Orthop Relat Res* 2010;468:3168-3180.
2. Yasunaga Y, Yamasaki T, Ochi M. Patient selection criteria for periacetabular osteotomy or rotational acetabular osteotomy. *Clin Orthop Relat Res* 2012;470:3342-3354.
3. Jakobsen SS, Overgaard S, Søballe K, et al. The interface between periacetabular osteotomy, hip arthroscopy and total hip arthroplasty in the young adult hip. *EFORT Open Rev* 2018;3:408-417.
4. Sutter M, Hersche O, Leunig M, Guggi T, Dvorak J, Eggspuehler A. Use of multimodal intra-operative monitoring in averting nerve injury during complex hip surgery. *J Bone Joint Surg Br* 2012;94:179-184.
5. Sierra RJ, Beaule P, Zaltz I, et al. Prevention of nerve injury after periacetabular osteotomy. *Clin Orthop Relat Res* 2012;470:2209-2219.
6. Tewari A, Francis L, Samy RN, et al. Intraoperative neurophysiological monitoring team's communiqué with anesthesia professionals. *J Anaesthesiol Clin Pharmacol* 2018;34:84-93.
7. Kamath AF. Bernese periacetabular osteotomy for hip dysplasia: Surgical technique and indications. *World J Orthop* 2016;7:280-286.